

CLAIMS:

1. A linear polypropylene homopolymer or copolymer exhibiting a melt strength of at least 2.5 g, determined by the haul-off method, comprising a high molar mass portion and a low or medium molar mass portion, the high molar mass portion having a Melt Flow Rate (MFR₂) of less than 0.1 g/10 min and the low or medium molar mass portion having a Melt Flow Rate (MFR₂) of more than 0.5 g/10 min, the polymer having a Melt Flow Rate (MFR₂) of 0.1 to 20 g/10 min.

10 2. The polypropylene homopolymer or copolymer of claim 1 exhibiting improved melt strength observed in dynamic rheology as increased nominal viscosity at low shear rates of less than 0.1/sec, and having a MWD of more than 6.

15 3. The polypropylene homopolymer or copolymer of claim 1 or 2, exhibiting a melt strength of at least 5 g, determined by the haul-off method.

20 4. The polypropylene copolymer of ^{claim 1}~~any of claims 1 to 3~~, comprising 0.1 to 20 mole-% of ethylene residues.

25 5. Polymer product, comprising at least 50 % by weight of a polymer according to ^{claim 1}~~any of claims 1 to 4~~.

6. The polymer product according to claim 5, comprising 1 to 40 wt-% of a rubbery component.

7. The polymer product according to claim 6, wherein the rubbery component is selected from the group of elastomers produced by copolymerizing at least propylene and ethylene, ready-made elastomers and natural elastomers.

30 8. A process for preparing linear high melt strength propylene homopolymers and copolymers comprising the steps of

- subjecting propylene and optionally other olefins to polymerization in a plurality of polymerization reactors connected in series,
- employing different amounts of hydrogen as a molar mass modifier in at least two of the reactors, and
- carrying out the polymerization reaction in the presence of a catalyst system capable

35

Sub B6

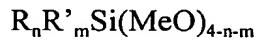
Sub 56

of catalyzing the formation of a high molar mass polymerization product having a MFR₂ of less than 0.1 g/10 min and a low or medium molar mass polymerization product having a MFR₂ of more than 0.5 g/10 min.

5 9. The process according to claim 8, wherein the polymerization reaction is carried out in the presence of a catalyst system, which is capable of catalyzing the formation of a high molar mass polymerization product having a MFR₂ of less than 0.04 g/10 min and a low or medium molar mass polymerization product having a MFR₂ of more than 0.5 g/10 min.

10 10. The process according to any one of claim 8 or 9, wherein the catalyst is capable of catalyzing the formation of said high molar mass product and said low or medium molar mass product at a pressure of 25 to 80 bar and at a temperature of 60 to 100 °C in a loop reactor.

15a 11. The process according to ~~any one of claims 8 to 10~~^{claim 8}, wherein the catalyst comprises a catalyst component, a cocatalyst component, an external donor and, optionally, an internal donor, the procatalyst component of the catalyst system containing magnesium, titanium, halogen and an electron donor, said catalyst system further containing an external donor having the general formula of



wherein R' and R can be the same or different and represent branched or cyclic aliphatic, or aromatic groups, and n and m are 0 or 1 and n + m is 1 or 2.

25 12. The process according to claim 11, wherein the external donor is selected from the group consisting of dicyclopentyldimethoxy silane, di-*tert*-butyldimethoxy silane, diisopropylidemethoxy silane and diisobutylidemethoxy silane.

a 30 *Sub 1*

35

13. The process according to ~~any one of claims 9 to 10~~^{claim 9}, wherein the catalyst comprises a catalyst component, a cocatalyst component, an external donor and, optionally, an internal donor, the procatalyst component of the catalyst system containing magnesium, titanium, halogen and an electron donor, said catalyst system further containing an external donor having the general formula of



Skr
D
cont

wherein R' and R" are the same or different and stand for a branched aliphatic or cyclic or aromatic group.

5 14. The process according to claim 8 or 9, wherein the catalyst system comprises a
metallocene catalyst.

15. The process according to claim 14, wherein the metallocene compound in the metallocene catalyst is bridged bis(2-R-4-R'-indenyl) M Cl₂, wherein both R and R' are aliphatic, cycloaliphatic or aromatic hydrocarbons having 1 to 18 C atoms, R' is typically phenyl or naphthyl, and R is a lower alkyl, M is a transition metal, and R and R' may contain heteroatoms, such as silicon, nitrogen, phosphorous or germanium, and the bridge between the indenyls comprises 1 to 3 atoms, such as carbon, silicon, nitrogen, phosphorous or germanium.

~~16. The process according to claim 15, wherein the metallocene compound is dimethylsilyl-bis(2-methyl-4-phenyl-indenyl)zirconiumdichloride.~~

claim 1

17. The process according to ~~any one of the preceding claims~~, wherein 5 to 50 % of the propylene homopolymer or copolymer has a MFR₂ < 0.1 g/10 min and 50 to 95 % of the propylene homopolymer or copolymer has a MFR₂ > 0.5 g/10 min.

a 18. The process according to ~~any one of the preceding claims~~, wherein said reactors are selected from the group of loop reactors and gas phase reactors.

25

19. The process according to claim 18, wherein said reactors comprises at least one loop reactor and at least one gas phase reactor.

S N 4

30

20. The process according to claim 19, wherein said reactors comprise a loop reactor and a gas phase reactor in that order.

Sub B8

18

~~claim 1~~
21. The process according to ~~any one of the preceding claims~~, wherein ethylene is fed into the reactor in which the higher molar mass component is produced in order to increase reactivity and molar mass of the component.

35

22. The process according to ~~any one of the preceding claims~~, which comprises the steps of

- Sub B8*
- subjecting propylene and optionally other olefins to a first polymerization or copolymerization reaction in a first reaction zone,
 - recovering the first polymerization product from the first reaction zone,
 - feeding the first polymerization product to a second reaction zone,
 - feeding additional propylene to the second reaction zone,
 - subjecting the additional propylene to a second polymerization reaction in the presence of the first polymerization product to produce a second polymerization product, and
 - recovering the second polymerization product from the second reaction zone, and
 - separating and recovering the polypropylene from the second reaction product.

5 23. The process according to claim 22, wherein the first polymerization or copolymerization reaction is in a reaction medium, at least 60 weight percent of which is formed by propylene, producing a polymerization product in particulate form.

10 24. The process according to claim 22, wherein the first polymerization reaction is carried out in a loop reactor.

15 25. The process according to claim 23 or 24, wherein the pressure of the first polymerization product including the reaction medium is reduced after the first reaction zone in order to evaporate volatile components of the product.

20 26. The process according to claim 25, wherein the pressure of the first polymerization product is reduced in a flash tank.

25 27. The process according to claim 25 or 26, wherein an overhead stream obtained from the evaporation of volatile components is condensed, a concentrated fraction of propylene being recovered from the condensed stream and recirculated to the first reactor.

30 28. The process according to ~~any one of the preceding claims~~, wherein the second reactor is a gas phase reactor, wherein propylene and optionally comonomers are polymerized in a gaseous reaction medium.

claim 1

35 29. The process according to claim 28, wherein the pressure of the second polymerization product including the gaseous reaction medium is reduced after the second reactor in order to separate part of the gaseous and possible volatile components of the product.

30. The process according to claim 27, wherein the pressure of the second reactor is reduced in a flash tank.

31. The process according to claim 28, wherein the overhead stream or part of it is recirculated to the second reactor.

32. The process according to any one of claims 21 to 28, wherein the second polymerization product is fed into a third reactor and propylene is subjected to a third polymerization reaction to produce a third polymerization product.

33. The process according to claim 30, wherein the third polymerization reaction is carried out in a gas phase reactor in the presence of comonomers which give the third polymerization product properties of improved impact strength.

34. The process according to any one of claims 32 or 33, wherein the product of polymerization reaction is transferred to a fourth polymerization reaction zone.

35. The process according to claim 8, wherein

- propylene and optionally other olefins are polymerized in a loop reactor at a pressure of 25 to 80 bar, at a temperature of 60 to 100 °C to provide a low or medium molar mass polymerization product of $\text{MFR}_2 > 0.5$,
 - the polymerization product of the loop reactor is recovered and conducted to a flash tank, wherein an overhead product containing hydrogen and non-reacted propylene is separated from a bottom product containing polymerized solids,
 - the bottom product is conducted to a gas phase reactor,
 - additional propylene and optionally other olefins are fed to the gas phase reactor,
 - the additional propylene and optionally other olefins are subjected to polymerization at a pressure of 20 bar or more to provide a high molar mass polymerization product of $\text{MFR}_2 < 0.1$,
 - the polymerization product of the gas phase reactor is recovered and conducted to a flash tank, wherein the pressure of the product is reduced to produce an overhead product containing hydrogen and non-reacted propylene and a bottom product primarily containing polymerized solids,
 - at least a part of the overhead product is recycled to the gas phase reactor, and
 - polypropylene polymer or copolymer is recovered from a part of the bottom product of the flash tank.

36. The process according to claim 35, wherein at least a part of the overhead product is recycled to the loop reactor.

37. The process according to claim 36, wherein the overhead product is conducted to the
5 gas phase reactor after at least a partial separation of hydrogen.

38. The process according to claim 8, wherein

- propylene and optionally other olefins are polymerized in a loop reactor at a pressure of 25 to 80 bar, at a temperature of 40 to 100 °C to provide a high molar mass polymerization product of $MFR_2 < 0.1$,
 - the polymerization product of the loop reactor is conducted directly to a gas phase reactor fluid bed,
 - additional propylene and optionally other olefins are fed to the gas phase reactor,
 - the additional propylene and optionally other olefins are subjected to polymerization at a pressure of 20 bar or more to provide a low or medium molar mass polymerization product of $MFR_2 > 0.5$,
 - the polymerization product of the gas phase reactor is recovered and conducted to a flash tank, wherein the pressure of the product is reduced to produce an overhead product containing hydrogen and non-reacted propylene and a bottom product primarily containing polymerized solids,
 - at least a part of the overhead product is recycled to the gas phase reactor, and
 - polypropylene polymer or copolymer is recovered from a part of the bottom product of the flash tank.

39. The process according to any claims 8 to 13, wherein the catalyst system has been prepared by

- providing a procatalyst by reacting a magnesium halide compound, selected from the group consisting of magnesium chloride, a complex of magnesium chloride with ethanol and other derivatives of magnesium chloride, with titanium tetrachloride and an internal donor,
 - providing as a cocatalyst an organoaluminium compound selected from the group consisting of trialkyl aluminium, dialkyl aluminium chloride and alkyl aluminium sesquichloride,
 - providing an external donor having the general formula $R'_{\text{2}}(\text{MeO})_{\text{2}}\text{Si}$, wherein R' stands for a cyclic or branched aliphatic, or aromatic group, for example dicyclopentyl dimethoxysilane or di-t-butyl dimethoxysilane, and, optionally,

- S
C
M*
- 5
- Sub 50
a*
- 10
- a
a*
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65
- 70
- 75
- 80
- 85
- 90
- 95
- prepolymerizing a small amount of olefin by contacting the olefin with said procatalyst, cocatalyst and the external donor.

40. The process according to claim 39, wherein the catalyst system has been transesterified with a phthalic acid ester - a lower alcohol pair, which transesterifies the catalyst at a temparature of 110 to 150 °C.

41. A product prepared by a process according to ~~any of the preceding claims~~, which is nucleated for higher crystallization temperature, stiffness and optical properties.

42. Use of a homopolymer or copolymer according to ~~any of claims 1 to 4~~ or a polymer product according to ~~any of claims 5 to 7~~ for the manufacture of polymer foams, thermoformed and foamed products, films and sheets, and products prepared by blow molding, stretch blow molding, injection moulding or calendering.

claim 1

claim 1